# CULTIVATION OF NEGLECTED TROPICAL FRUITS WITH PROMISE

## Part 3. The Pummelo

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# ILLUSTRATIONS



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# CULTIVATION OF NEGLECTED TROPICAL FRUITS WITH PROMISE

## Part 3. The Pummelo

By Franklin W. Martin and William C Cooper[1]

## ABSTRACT

The pummelo, *Citrus grandis* (L.) Osbeck, is the most tropical of the citrus fruits, yet is poorly distributed, underutilized, and often unknown. It is an excellent fruit, however, which finds ready acceptance wherever tried. Pummelos probably originated in China but were carried to Thailand, Malaysia, and Indonesia, where their evolution has continued and where many varieties are now available. The tree is large and spreading, with large, winged leaves, and frequently with thorns. The flower is very large for a citrus (3–5 cm in diameter), and the fruits vary from large to extra large. The rind is often thick. At maturity the sweet to subacid fruit vesicles separate easily from the membrane of the segments and are served in a dish as a dessert fruit. Varieties of pummelo can be classified as Thailand group (best tropical varieties), Chinese group (better suited to subtropics), and Indonesian group (extremely variable and sometimes inferior). The pummelo produces a monoembryonic, normal, sexual seed, and thus can be improved by breeding. Improved varieties are maintained by bud and cleft grafting as well as by marcotting. Culture is similar to that of other citrus trees, but the trees need somewhat larger growing areas. Cover crops or cash crops can be planted among the trees until they are too large. Normal chemical treatment schedules for pests and weeds can be used, but have not been adequately tried with the pummelo. Some pummelos are tolerant to foot rot, a disease that always requires careful treatment. Since flowering may occur several times a year, fruiting is irregular, but usually one harvesting season predominates. The fruit is picked just as it yellows or later, and is more flavorful when stored for several months. Because of its thick rind, the pummelo is easy to ship and keeps well even in common storage. **KEYWORDS: fruit, citrus, pummelo, pummelo cultivation, shaddock, tropical fruit, tropicial fruit cultivation.**

## INTRODUCTION

From the Orient, inciuding India and Southeast Asia, citrus fruits have gradually encircled the globe. They have become so commonplace in the Tropics and in certain regions of the Temperate Zone that they seem to be a part of the original landscape. Almost all species have found locales suited to their cultivation and a variety of uses. During their geographical march, the species have been hybridized, sometimes spontaneously and sometimes by means of man's guidance. The number of species, hybrids, and varieties is large and

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diverse. During this process, one important species was especially neglected, the pummelo, *Citrus grandis* (L.) Osbeck. While distributed throughout the Tropics of Southeast Asia and highly appreciated there, it is still little known and remains underappreciated in the American Tropics. Its potential has not been realized because programs for the introduction, seedling selection, hybridization, and varietal testing of the pummelo have been lacking.

The pummelo, however, should not be neglected in the hot Tropics. As a fruit more tropical than subtropical, it should be at home in the hot, humid Tropics where other citrus fruits do not perform at their best. Pummelos are frost sensitive and out of place in many areas of the United States where citrus is produced. Although the varieties from Thailand may need rather special environments, pummelos in general are broadly adaptable within the American Tropics. The tolerance of pummelos to soil extremes is shown by the success of some pummelos growing on infertile tin tailings in Malaysia.

Near the center of its origin, possibly China, the pummelo is the favorite citrus fruit. It is the fruit mentioned earliest in Chinese literature. In a tribute to the Chinese emperor Yu Kung, who ruled from 2205 to 2197 B.C., the following statement appears, "The baskets were filled with ornamental silks. The bundles contained small oranges and pummelos" (*23*).[2] Pummelos were one of the first citrus species to be introduced to Europe, following the steps of the citron, the 'Sour' orange, and the 'Sweet' orange from China through Indochina, to the Middle East, Persia, Greece, Italy, Spain, and North Africa. It was mentioned as Adam's apple when seen in Palestine in 1187, and in about 1250 it was described as a fruit of Palestine. Probably, it reached Spain about the same time by means of Arab influence. Ferrari (*8*) described several varieties in Europe.

The pummelos grown in the Mediterranean region failed to develop the fine quality for which these fruits are known in the Orient. We now know that the cool Mediterranean climate is not conducive to the development of the low acid content required for high quality in both the grapefruit and the pummelo (*5*). Both these species should be grown in semitropical, tropical, or a hot desert climate to achieve the best blend of sugar and acids for these fruits. The Thailand group of pummelo varieties requires a tropical climate for optimum fruit quality.

On the other side of the world, the pummelo was distributed in pre-Columbian times through Southeast Asia and to Fiji and the Friendly Islands.

There is no exact record of when it reached the New World, but the literature mentions the introduction of the pummelo into Barbados as occurring before 1696 (probably 1675) by Captain Shaddock, who distributed seeds from Indonesia. His name has come to be a common name for the pummelo.

The early importations (1902–1909) of pummelos into the United States were made without special reference to the fruit quality of the varieties imported (*11*). They were grown mainly as curiosities, because they produce fruits larger than a man's head and weigh 7 to 10 kg. Such large fruits, however, are commonly of inferior quality.

Between 1910 and 1913, attempts were made by the Offices of Crop Physiology and Breeding and Foreign Seed and Plant Introduction, U.S. Department of Agriculture, to introduce and establish the culture of the best kinds of pummelos in the citrus-growing regions of the United States and the Philippines (*16*). After quarantine, varieties were distributed in the United States, and there are now trees bearing at the University of California at Riverside, the U.S. Date and Citrus Station, Indio, Calif., and the U.S. Horticultural Research Laboratory, Orlando, Fla. Although these introductions are of the superior kinds highly prized in the Orient, they have failed to develop an equal quality in California, except in the hot desert valleys such as at Indio. This is to be expected since much of California has a climate similar to the Mediterranean region. However, a few of these varieties have produced fruit of reasonably good quality in Florida.

The chief regions where pummelos are cultivated today are Thailand, Vietnam, and southern China. Pummelos are also well known in Malaya, Indonesia, Burma, and the Philip-

[2] Italic numbers in parentheses refer to items in "Literature Cited" at the end of this publication.

pines. In India and the islands of the Pacific, pummelos are less well known. Pummelos are not grown commercially in other parts of the world, except on a small scale.

Pummelos have almost disappeared from Europe. They are occasionally found in Africa, especially West Africa, and in Central and South America. They are grown to a small extent in Australia and the northernmost parts of New Zealand. Pummelos have not become popular in the West Indies, even though excellent varieties have been introduced.

For the most part, the pummelo has remained a species of interest principally for breeding purposes, because of their enormous fruits. Few are being grown outside the experiment stations. Part of the reason for the neglect may also be that the pummelo is principally a tropical rather than a subtropical species and has not been well tested in areas most natural for it. Even so, excellent varieties are available. The greatest need is the wide dissemination of the available varieties in the American Tropics so that it may become better known.

## THE PUMMELO

### Origin

It is difficult to establish the exact geographical origin of the pummelo. Because many wild pummelo seedlings are widely distributed in Indonesia and Malaysia (*3*), Webber (*24*) and Ochse (*14*) consider it to be native to this region. However, there is evidence that the pummelo and many other citrus species were taken throughout Southeast Asia by Chinese settlers and that the pummelo has become feral in these regions (*5*).

When Han Wu Ti conquered the Shan kingdom around Canton in 118 B.C., the pummelo was found to be commonly grown in this region under the name "Yau" (Chinese Imperial Encyclopedia on file at the Library of Congress). During the 11th century A.D., there was a strong migration of Shans to Burma, Assam, Siam, the Malay Peninsula, and Indonesia, and they likely carried citrus fruits, including pummelos, from the Canton region with them. The Shans who settled in Siam are known as Thai people, and those in Indochina are known as Lao, and so on. In each of these areas of Southeast Asia and Indonesia, these Shans, or Chinese settlers, became farmers and are the early Chinese horticulturists to whom the world owes many of its varieties of citrus.

### Botanical Description

The pummelo, *Citrus grandis* (L.) Osbeck [synonym: *C. maxima* (Burm.) Merr.] is distinguished by a wide variety of common names. In Indonesia, it is limau (lemon), usually distinguished with a modifier, such limau bali (Balinesian lemon) or limau betawi (Batavian lemon). The name "jambua" is also used. In Thailand, the names are som-o or ma-o. The name "pummelo" appears to be a contraction of the Dutch word pompelmoes or pomplemoose. Common names include pummelo and shaddock (English), pomelo and toronja (Spanish), toranja and laranja-melancia (Portuguese), pampelmousse, pampelmoussier, and pomme d'Adam (French), and pampelmus and Adamsapfel (German). The common name "pummelo" is most favored.

This description of the species closely follows that of Swingle (*19*). The pummelo is usually easily distinguished as a tree or as a fruit. It is a large, somewhat open, spreading tree that reaches 5 to 15 m in height. The trunk is divided into several principal, sprawling branches that, if unpruned, tend to droop and reach the ground (fig. 1). It may appear to be a large, overgrown shrub. The bark is

FIGURE 1.—A mature tree of the pummelo variety 'Tresca' in Puerto Rico.

FIGURE 2.—Leaves of the pummelo, showing the winged petiole.

mottled, and the wood is white to yellowish, close grained, and hard.

Young stems are thick, angular, and often pubescent. The leaves are huge for a *Citrus*, 5 to 20 cm long and 2 to 12 cm wide (fig. 2). The lamina is ovate to elliptic or ovate-oblong. The base is obtuse, rounded, or subcordate, and the tip is obtuse or obtusely acuminate. The underside of the midrib is sometimes pubescent. The leaves are dark green and shiny above and pale beneath. The petioles are broadly winged, with the lamina in the same plane and continuous with the leaf. Spines of 1 to 5 cm in length are commonly borne on branches of pummelo seedlings, but older plants lose these thorns. Young twigs on mature trees are fairly thornless. In almost every case, old varieties propagated by marcottage are thornless.

Flowers of the pummelo are among the largest found in *Citrus*, about 3 to 7 cm in diameter, occurring singly or in clusters of up to 10 in the leaf axils or near the ends of the branches. The calyx is four- or five-lobed and the four or five petals are white or cream colored. There are 20 to 25 stamens and 11 to 16 loculi in the ovary.

The fruit of the pummelo is large, 10 to 30 cm in diameter. Fruits more than 60 cm in diameter and 10 kg in weight have been reported. They are globose, slightly flattened, or pear shaped. The apex may be round or slightly depressed. The style and stigma may be persistent. The fruit at maturity is light green to golden yellow. The surface is characterized by greenish dots, which are oil glands. The rind is soft, pithy, pink or white, and from 1 to 3 cm thick. The surface of some fruit is downy. The rind usually can be easily removed. The center or axis of the fruit may be solid but is more commonly open. In the better varieties the center is closed. The segments of the fruit are usually easily separated and often split open towards the core. The membrane is thin to thick, usually tough, but separates easily from the large vesicles without spilling of juice. The pulp is from white to yellowish, pinkish, or rose red. The pink color results from the carotenoid pigment lycopene. Seeds are large, ridged, yellowish, few to many, and horizontal or pendulous. When grown in plantings with other citrus fruits, pummelos are seedy; in isolation, some varieties produce few, if any, seeds.

The pummelo is sometimes confused with the grapefruit, a possible hybrid that may have arisen in the West Indies. The two types of fruit are easy to distinguish, however, and normally differ in taste and in use. Webber (*24*) distinguishes the pummelo and the grapefruit as follows:

| *Pummelo* | *Grapefruit* |
|---|---|
| Young twigs pubescent | Twigs glabrous. |
| Leaves puberulent beneath along midvein. | Leaves glabrous. |
| Petioles very broadly winged. | Petioles broadly winged. |
| Fruit size large to very large. | Fruit size medium to large. |
| Fruits mainly spherical, obovate, or pyriform. | Fruits mainly oblate, spherical, or obovate. |
| Rind thick to very thick | Rind thin to medium thick. |
| Segments mainly open at center. | Segments closed at center. |
| Axis semihollow or hollow | Axis solid or semihollow. |
| Pulp tough and solid | Pulp tender and melting. |
| Seeds monoembryonic | Seeds polyembryonic. |
| Fruits mainly borne singly | Fruits mainly borne in clusters. |

Pummelos exhibit a much wider range of variation in characteristics than do grapefruit. Some pummelos are comparatively small trees, such as the low-headed, dwarfish 'Daang Ai Chaa', or 'Red Bantam', pummelo of Thailand, said to resemble a squatting chicken (*11*). Other pummelos are among the largest citrus trees. The range in fruit size, form, and rind thickness is especially notable (fig. 3). The largest of all citrus fruits are pummelos, and they exhibit the thickest rinds. Pear-shaped

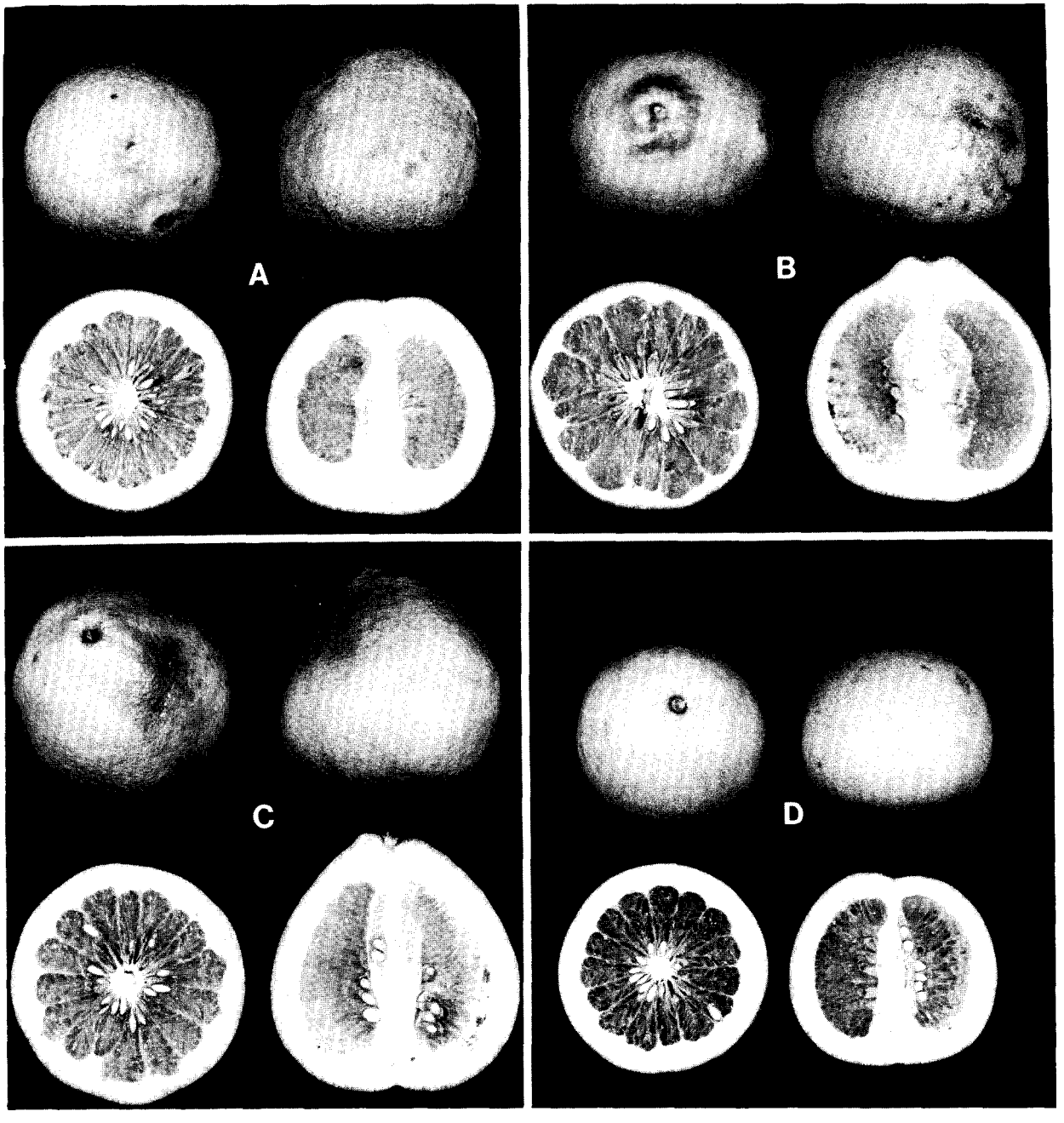


FIGURE 3.—Fruits of four varieties of pummelo: *A*, 'Kao Panne'; *B*, 'Kao Phuang'; *C*, 'Reinking'; *D*, 'African'.

pummelos are common, and some are ovoid. The flavor ranges from insipidly sweet to highly acidic, though many are pleasantly flavored. Some fruits are pigmented and others not. Finally, some few have a navel, such as the so-called "double pummelo" in the Molucca Islands (*15*).

## Varieties

If the origin of the pummelo is southern China, the Chinese pummelo is the ancestral parent of all pummelos. However, the pummelos grown and selected over the centuries in Thailand are less cold hardy and probably have

better fruit quality than the Chinese varieties. Likewise, the Thailand varieties are smaller and have better fruit quality than the Indonesian varieties. Therefore, for convenience we have divided the pummelo varieties into three groups based on the region of production.

**The Thailand group**

The Thai varieties are round or flattened or pear shaped, small in size, and of excellent quality. They are reputed to be well adapted to the high water tables and salinity of the low-lying swampland, dotted here and there by nipapalms (*Nipa fruticans* Wurmb) in the districts of Nakon (also spelled Nakorn) Chaisri and Bang Bakok (*11*). The pummelo development in these areas is the result of the digging of canals and ditches and the raising of beds of soil upon which trees are grown, much as is done by citrus growers in the Indian River section of Florida. Drainage and irrigation are thereby affected by this one operation. The Chinese settling in the area were eminently fitted, because of their centuries of experience in this type of water farming, to reclaim and place this low-lying land under cultivation. The beneficial effect of salt in pummelo culture is probably overrated. Good drainage of these raised beds is the key to successful cultivation of the pummelo, as with the culture of most citrus species. Furthermore, Cooper and Gorton (*6*) have shown that pummelo seedings used as rootstocks for grapefruit trees showed poor salt tolerance in artificially salted soils plots in the Rio Grande Valley of Texas.

At present, great confusion exists in the names for the Thailand group of pummelos. Whereas these pummelos have native names such as 'Kao Panne', 'Kao Phuang', and 'Thong Dee', they are generally known on foreign markets as the 'Siamese' pummelo and in the local Thai markets by the name of the district where they happen to be produced, as is the case with the 'Kao Panne' pummelo produced in the Nakon (Nakorn) Chaisri district.

Another complication with the varietal names of Thai pummelos is that in the Philippines some of the introductions from Thailand have received Western names. Thus, 'Bangkok', 'Boyle', 'Nakon', and 'Siam' are largely traceable to the introductions of H. H. Boyle (*1*) in 1912–13, to which P. J. Wester assigned names (*11, 26*). Later, some of these Thai pummelos were introduced to the United States directly from Thailand, carrying the native names (*11, 16*). Thus, the same variety may be grown in California and Florida under different names, depending on whether the introductions came directly from Thailand or by way of the Philippines.

A third complication in the names is whether the introduction consisted of seed or of budwood. Most pummelos are self-sterile, or nearly so, and consequently are produced from cross-fertilization, and the progeny from these seeds will be highly heterozygous and each seedling progeny will be different from either of its parents (*19*). Nevertheless, seedling populations of open-pollinated pummelo seedlings, all of which are zygotic, appear in general to be rather uniform in size and growth habit, as compared with seedlings derived from zygotic embryos of other citrus species. Of course, a detailed and careful examination of pummelo seedlings will show that no two are precisely alike in vegetative characters and, when grown to fruiting, will likely show considerable variation in fruit size, shape, color, and acidity. Selections made from these seedlings will not bear true-to-name fruit of the seed-parent variety. Promising seedling selections should eventually be given a new name and not be carried under the same variety name as the seed parent.

The numerous commercial varieties of Thai pummelos are naturally divided into three classes: (1) the subglobose, or flattened, neckless forms of which 'Kao Panne' is the characteristic variety, (2) the elongated, pear-shaped, necked type as described under 'Kao Phuang', and (3) the intermediate type of which 'Thong Dee' is characteristic.

*'Kao Panne'.*—As grown in the Nakon Chaisri district of Thailand, the fruit is subglobose and small (for a pummelo), averaging 11 cm in diameter and 10 cm in height (*11*). Its rind is a lemon-yellow color, smooth, and medium thick. The oil glands are rounded, about half the size of a pinhead, grouped uniformly about 1.5 mm apart. The segments are numerous (12 to 15), the carpellary membranes thick and tough, and the core small and solid. The juice sacs are large, easily separated,

and moderately juicy. The flavor is sweet and mildly acidic. This variety matures early.

The 'Kao Panne', or "White Flat" pummelo, doubtless originated in the Nakon Chaisri district, where it is also known as the 'Nakon Chaisri' pummelo. Nang Nui, the woman owner of the best 'Kao Panne' orchard in Ban Mai of the district, told the junior author while visiting Ban Mai in 1969 that the 'Kao Panne' had been known for only two or three generations. Her mother had claimed that not more than 100 years ago only a few trees of this variety grew at Ban Mai. This woman's family had grown fruit for about 70 years, having cleared the nipapalm swamp where the present grove is located.

Other 'Kao Panne' type pummelos described by Groff (*11*) include 'Koon Non', 'Kao Yai', 'Daang Ai Chaa', 'Kao Phloeng', and 'Hom Bai Toey'.

*'Kao Phuang'*.—Widely grown in the Bang Bakok region of Thailand, this is the pear-shaped type so often sold on Far Eastern markets under the name of 'Siam' or 'Siamese'. It is also known as the "White Tassel" pummelo. In marked contrast to the spreading, well-rounded head common to 'Kao Panne' trees, those of 'Kao Phuang' are decidedly upright in growth habit (*11*). The 'Kao Phuang' trees are more healthy and vigorous and are heavier bearers than those of the 'Kao Panne'. The excellent shipping qualities of the 'Kao Phuang' are widely recognized, and it is probably a better variety than the 'Kao Panne'.

The fruit (grown in Bang Bakok) is elongated, pear shaped with a distinct neck, and seedy. Its size is at least 12 cm in diameter and 13 cm in height (*11*), its color greenish to yellow, and its rind smooth, glossy, and less tightly adherent than the 'Kao Panne'. The segments are numerous and easily separable, the carpellary membranes thick and tough, and the core small and solid. The vesicles are easily separable and firm but juicy. The flavor is good but more acidic than the 'Kao Panne'. It matures at midseason and holds well on the tree.

At Indio, Calif., the flavor of the 'Kao Phuang' is superior to that of the 'Kao Panne', and it matures early. Because of its superior vigor, fruitfulness, and fruit flavor, the 'Kao Phuang' is preferred to the famous 'Kao Panne'.

Other 'Kao Phuang' type pummelos described by Groff (*11*) include 'Kao Lang Sat' and 'Kao Ruan Tia'.

*'Thong Dee'*.—The fruit is neither globose nor pear shaped, but somewhat flattened (*11*). Its size is large, measuring 15 cm in diameter and 11 cm in height. The rind is medium thick, smooth, and tightly adhering. Under favorable conditions both albedo and flesh are pink tinged. The carpellary membranes are thin but tough and readily separable from the pulp. The vesicles are large, and juice is plentiful. The flavor is good but not so delicious as that of the 'Kao Panne' and 'Kao Phuang'. The fruit is seedy. It is also known as the "Golden" pummelo.

A seedling tree of 'Thong Dee' (PI 52389) growing in the variety block at Orlando, Fla., produces fruit similar to Groff's description for this variety. It bears large, seedy, pink-fleshed fruit of good quality but not as high quality as the 'Nakon' and 'Siamese' varieties.

*'Nakon' ('Nakorn')*.—This variety was introduced as seed from fruit of the 'Nakon Chaisri' ('Nakorn Chaisri') pummelo as CPB 10091 and PI 52388. Groff (*11*) considers 'Nakon Chaisri' as a synonym for 'Kao Panne'. However, fruit from the 'Nakon' seedlings grown at Orlando, Fla., is small and broadly pyriform, and that of 'Kao Panne' (grown at Indio, Calif.) is subglobose to spherical. The reason for the discrepancy doubtless lies in the fact that the introduction of 'Kao Panne', now at Indio, was a budded plant, but it was seed in the case of 'Nakon'. We consider 'Nakon' as a separate and new variety.

The fruit is small (10 cm in diameter), pyriform shaped, and seedy when grown in a mixed variety planting at Orlando, Fla. It is lemon yellow at maturity (midseason), white in flesh, and of excellent flavor. The fruit hangs on the tree long after maturity.

*'Siamese' (probably 'Kao Phuang')*.—This variety was introduced as budwood under CPB 14012 and PI 109708 from the Philippines to the United States. Eugene May obtained the budwood from P. J. Wester at Los Banos, Philippines. May's records show that P. J. Wester considered this one of the best 'Siamese' pummelos introduced up to that time (*11*).

This is the pummelo that Wester (*26*) described as 'Siam', and he correctly believed that it had not yet been introduced into the United States. Groff (*11*) believes that this variety is the same as the 'Kao Phuang' pummelo of Bang Bakok, which he and Otto Reinking introduced into the Philippines under CA 16931 and into the United States under CPB 10088 and PI 109689.

Presently, only the CPB 14012 is grown at Orlando, Fla., whereas only the CPB 10088 is grown at Indio and Riverside, Calif. Until fruit is available for comparison of the two introductions grown at the same location, we are considering the 'Siamese' introduction to be a separate variety.

The fruit of the 'Siamese' variety grown at Orlando is large, 13 cm in diameter and 17 cm in height, obovate with a neck. The rind is light yellow at maturity (early to midseason) and is 2 cm thick. The segments are numerous, the carpellary membranes tough, and the core small and solid. The flesh is coarse grained and white, the vesicles large, easily separable, and firm, and of excellent flavor. The tree is more vigorous and upright than the 'Nakon' tree.

*'Chandler'*.—This is a cross of the 'Siamese Sweet' with pollen from a 'Siamese Pink' (*2*). The 'Siamese Pink' is pink fleshed and has a relatively high acid content (1.5%), and the 'Siamese Sweet' is white fleshed and has a low acid content (0.1%). The sugar content of both parents and the hybrid is around 12%. The hybrid, 'Chandler', is pink fleshed like the pollen parent, but otherwise it is intermediate in characteristics between it and its two parents (*20*).

Several desirable characteristics of the parents are combined in 'Chandler'. It has a thinner rind, smaller core, thinner segment membranes, and a finer texture than either of its parents. It ripens earlier and has a better overall flavor than either parent. This variety should be tried in the American Tropics.

*'Reinking'*.—This is a selection (not yet released as a variety) coming out of the pummelo breeding program by J. R. Furr at Indio, Calif. The selection is a seedling coming from the program of a cross of 'Kao Phuang' and 'Shamouti' orange. The selection, however, is not a pummelo-orange hybrid and is probably the result of contamination by pummelo pollen of some unknown origin, even though the cross was protected by bagging.

In the 25 seedlings from which the 'Reinking' seedling was selected, there were several siblings of nearly equal quality to that of 'Reinking'. The 'Reinking' has many of the desirable characteristics of the seed parent and is free of xyloporosis, which is carried by the seed parent.

**The Chinese group**

Chinese pummelo varieties are grown chiefly in Kwangsi, Kwangtung, and Fukien Provinces along the southeast coast of China, in Taiwan, and in the most southern portion of Japan (Kagoshima Prefecture). The climate in these regions, though semitropical to subtropical, is cool enough during the winter to induce a dormancy in pummelos. Under these conditions there is usually only one bloom flush (February and March) that produces one annual crop of fruit, usually harvested in December and January. This characteristic contrasts with the tropical climate of Thailand, where bloom flushes usually follow the onset of periodic rainy seasons, resulting in several bloom flushes.

Most pummelos, including the 'Sha Tin Yau' and 'Song Ma Yau' from Kwangsi and Kwangtung and the 'Mato Butan' of Amoy, are produced in the southern sections of China (*22*), but a pummelo hybrid called 'Shanyuan' is grown in the Yangtze valley (*13*). However, this particular one is not edible. After centuries of selection of varieties of the pummelo growers of China, some of their pummelo varieties probably carry more cold hardiness than the Thai varieties.

Chinese pummelo introductions to the United States now bearing fruit in the pummelo-variety block of the University of California at Riverside include 'Pong Yau' and 'Tau Yau'. All are medium to large productive trees with fruits that are broadly obovoid to short pyriform. The fruits have medium-thick rinds, and are juicy and of good flavor (*12*).

*'Mato' ('Mato Butan')*.—This is the principal variety grown in Punan (near Amoy), China. According to Hodgson (*12*), this variety was taken from China to Taiwan about 1700 A.D. and thence to Japan. 'Mato' is currently the

principal pummelo variety grown in Taiwan and ranks third in Japan. It is a small tree of the Thai type and resembles the 'Kao Phuang' to some extent.

The following description is adapted from Hodgson (*12*). The fruit is medium large, obovoid to pyriform, light yellow at maturity, and seedy. The rind is medium thick, tightly adhering, and the surface pebbled with protuberant oil glands. The segments are numerous, the carpellary membranes thin but tough, and the flesh white, crisp, lacking in juice but sweet. It matures early.

*'Amoy'*.—Wester (*25*) states that the 'Amoy' (probably a synonym for 'Mato') is the best in the Philippines. This statement, however, was made before the many fine Thai varieties were established there. The fruit is globose, medium sized, and has a tightly adhering rind. The flesh is white, lacking in juice but sweet, and it possesses an aroma peculiar to Chinese pummelos.

**The Indonesian group**

The Indonesia pummelos, including those from Malaysia and India, are tropical in adaptation, flexible in soil requirements, and extremely varied in fruit quality. These varieties grow best in tropical lowlands under conditions of good drainage. The fruits are commonly much larger than those of the Thai varieties. They are more or less globose or oblate in shape and have thick rinds. The pummelo is widely grown in Indonesia from seed, a custom that results in a wide range of variation of characters. Most of these seedling trees produce fruit weighing 7 to 9 kg and are commonly of inferior quality.

Because of the large number of seedlings grown in Indonesia and Malaysia, numerous selections of fine-quality fruit have been made and all now being propagated on pummelo, 'Rangpur' lime, and 'Rough' lemon rootstock (*13*). These are typified by the 'Pandan Wangi', 'Pandan Bener', 'Seeloompang', 'Bali Merah', 'Deleema Merah', 'Deleema Kopjor', and 'Banpeiyu' varieties (*14*).

Santiago (*18*) describes the 'Tambun' pummelo, several pink shaddocks, and a wild pummelo in Malaysia. All, except 'Tambun', were of poor quality with unusually thick rinds.

Several good quality, red-fleshed pummelos of the Indonesian group have been introduced into the United States and are now grown in pummelo-variety blocks in California and Florida. These include the 'India Red' pummelo, the 'Red Shaddock', the 'Pink Shaddock' ('Webber' pummelo), and the 'Hirado Buntan'.

*'Banpeiyu' ('Pai yau' in Taiwan)*.—Of unknown Malayan origin, this variety was introduced into Taiwan in 1920 and named in 1925, and it was later taken to Japan. This variety currently ranks first in Japan and second in Taiwan (*12*).

The fruit is large, oblate, and seedy, the rind thick and tightly adherent, the segments numerous, and the carpellary membranes thin but tough. The flesh is white, tender, and juicy, the flavor good. It is medium late in maturity and stores well (*12*).

*'Hirado Buntan'*.—This variety originated as a chance seedling in Nagasaki, Japan (undoubtedly from an Indonesian fruit), and is currently second in importance there (*12*).

The fruit is large, oblate, and seedy. The color is bright yellow when mature, the rind thick and tightly adherent, the segments numerous, and the carpellary membranes thin but tough. The flesh is white, tender but juicy, and the flavor pleasant. It is medium early in maturity and stores well (*11*).

*'Pandan Bener'*.—Ochse (*14*) describes this as one of the two best varieties in the Batavia district of Java. The fruit is large, oblate to globose, red fleshed, and pleasantly flavored. The tree is not very productive.

*'Pandan Wangi'*.—This variety ranks with 'Pandan Bener' as one of the two outstanding varieties of Batavia, Java (*14*). The large red-fleshed fruit is oblate to globose in form and is pleasantly sweet flavored. The tree is very productive.

*'Red Shaddock'*.—Introduced to the United States in 1924 from the Canal Zone, Panama, as PI 58840, it seems probable that this variety was brought from India or Indonesia in the early days. Trees of this variety are now bearing fruit at Indio, Calif., and Orlando, Fla.

The fruit is large, oblate in form, red fleshed, juicy, and of good quality. It matures early. The fruit tends to split, and the tree declines in productiveness after several years of heavy fruiting.

*'Webber' pummelo*.—This pink-fleshed fruit

(called Shaddock) was collected as a cutting in 1925 by H. J. Webber in Java and introduced to the United States as PI 109698 and CPB 10307. Grown at David Fairchild's place, Kampong, in Coconut Grove, Fla., the variety was named 'Webber' by Fairchild. The fruit is large, pink fleshed, of good quality, and early maturing.

*'Tambun' pummelo.*—The fruit is large, pink fleshed, with thick skin, juicy, of good quality, and often seedless. It is commonly grown at Tambun, near Ipoh, Malaysia (*18*).

*'African' pummelo.*—Collected as seed by R. A. Davis in Johannesburg, South Africa, this pink-fleshed pummelo was introduced to the United States in 1923 as PI 109695 and CPB 10210. This pummelo is probably not native to South Africa, but its origin is unknown. The fruit is small and round to slight necked. The tree grows vigorously and has been used successfully as a rootstock for other pummelos.

### Recommendations

Some of the choice varieties, as shown by trials in Florida, are 'Thong Dee' (seedling), 'Nakon', and 'Siamese'. At Indio, Calif., 'Kao Phuang', 'Kao Panne', 'Webber', and 'Red Shaddock' are good. The new variety 'Chandler' and the 'Reinking' selection from California are also of special value.

As in the case of all citrus fruits, quality is related to environmental factors. Pummelos are adaptable to the Tropics. Some varieties produce fair quality fruit in the subtropics but would probably produce higher quality fruit in the Tropics. Nevertheless, good fruit has been produced at Indio, Calif. Although still relatively untried, pummelos should be of high quality when produced in the Caribbean.

Choice quality appears to be related to appropriate tropical climate, use of good varieties, and propagation by air layering or by grafting on pummelo seedlings.

The following varieties are recommended for preliminary trial in Puerto Rico: 'Red Shaddock', 'Thong Dee' (seedling), 'Webber', 'Chandler', 'Kao Panne', 'Siamese', 'Reinking', and 'Nakon'. They have all been introduced to the Mayagüez Institute of Tropical Agriculture (MITA). The only variety known to be in Puerto Rico as mature trees is 'Tresca'.

## CULTIVATION

### Breeding

The pummelo, in contrast to other citrus species, produces a monoembryonic seed. The seeds are produced only by pollination and by means of a complete sexual process. The pummelo can, therefore, be crossed readily with other citrus fruits. When it is used as female parent, most if not all seeds from a controlled cross-pollination will be hybrid. Pummelos can be crossed readily among themselves to produce new, monoembryonic selections.

The pummelo may be partially or fully self-incompatible, meaning that some varieties, when grown in isolation, produce few if any seeds. When these are grown with other varieties, the fruits are seedy. The seedy characteristic of the fruit is one of the disadvantages of the species as a table fruit.

Some natural pummelo hybrids are suspected. The grapefruit is believed to be a hybrid of the pummelo and the 'Sweet' orange, *Citrus sinensis* (L.) Osbeck (*17*). However, every effort made to produce a grapefruit by crossing oranges and pummelos has failed. The many differences between the pummelo and the grapefruit make it unlikely that the latter is only a mutation. The grapefruit was first mentioned in 1814 in Jamaica and a few years later in Barbados. On the other hand, the variety 'Tresca' found in Florida is intermediate to the grapefruit and the pummelo, and thus of uncertain origin. The variety 'Frizzelle' is polyembryonic but resembles a sour pummelo rather than a grapefruit. The juice of the grapefruit variety 'Triumph' has an aroma reminiscent of the pummelo, suggesting, at least, a relationship.

As a rule, citrus species are not difficult to intercross. Nevertheless, poor pollen production and polyembryony interfere with hybrid seed production in some cases. The following pummelo crosses have been made by Furr (*9*): (1) 'Temple' × 'Red' pummelo produced tangelolike hybrid, inedible; (2) 'Temple' × 'Kao Phuang' produced tangelolike hybrid, inedible; (3) 'Temple' × 'Kao Ruan Tia' produced tangelolike hybrid, inedible; (4) 'Clementine' × 'Kao Ruan Tia' produced tangelolike hybrid, good quality; (5) 'Kao Panne' × 'Lake' tangelo produced grapefruitlike hybrid, excellent qual-

ity; (6) 'Kao Panne' × 'Minneola' tangelo produced grapefruitlike hybrid, excellent quality; (7) 'Kao Panne' × 'Webber' pummelo produced new pummelo selection with thin rind, juicy, excellent quality; (8) 'Red Blush' grapefruit × 'Webber' pummelo produced mainly pummelo types; (9) 'Red' pummelo × 'Red Blush' grapefruit produced mainly pummelo types.

It is likely that many of the undesirable genes in the fine quality Thai pummelo varieties have been eliminated through generations of selection in Thailand. In the 25 or 30 'Kao Phuang' seedlings from which 'Reinking' was selected at Indio, Calif., there were several siblings almost as good as the 'Reinking'. Also, the seedlings grown at Orlando, Fla., from open-pollinated seeds of 'Nakon Chaisri' and 'Thong Dee' fruit from Thailand produce high-quality fruit. The 'Kao Panne' × 'Webber' pummelo made by Furr (*9*) has produced a highly promising pummelo worthy of naming and releasing. Therefore, it seems likely that rapid progress could be made in the American Tropics by controlled crosses of the best named pummelo varieties.

Furthermore, to breed varieties best suited to the American Tropics, the selections should be made there. In making crosses in which the pummelo is used as the seed parent, the breeder should be aware that, unlike other species of citrus, the anthers of pummelo flowers usually mature and begin to dehisce before the flower opens. Perhaps the contamination of the stigma with its own pollen should not matter, but until it has been demonstrated that the particular variety is completely self-sterile and that its own pollen will not interfere with fertilization of the egg by other pollen, self-pollination should be avoided when attempting cross-pollinations.

Also, because of the early maturity of the pollen, to avoid contamination of the stigma, it is necessary to emasculate when the flowers are quite immature, that is, while the anthers and stigma are still green in color. At this stage it is somewhat difficult to avoid breaking the flower. Pummelo flowers are often borne in small clusters, so that many small twigs must be labeled and covered by bags. The emasculation of quite immature flowers may make it necessary to pollinate a day or two later, when the stigma becomes receptive. The breeding of pummelos may be considerably more tedious than the breeding of tangerines, but the seed yield is great for each fruit produced (*9*).

In the crossing of pummelos, fresh pollen may be obtained in the field by the collection of flowers of the pollen variety at the "balloon" stage just before the petals open. Usually the anthers will dehisce soon after collection if they are not already doing so when collected.

Some of the Oriental pummelo varieties, whether from Thailand, China, or Malaysia, when grown at the Orlando, Fla., Station are sweeter than grapefruit, and the flavor is distinctive and pleasing to most persons. Most pummelos are seedy (at least those grown in mixed variety plantings), and they have thick, tough rinds and carpellary membranes that make them difficult to eat out of hand or to prepare as salads. Also, their large size causes difficulties in packaging and marketing. For these reasons, consumers in the United States, who also like the pleasantly tart flavor of grapefruit, have not shown an interest in pummelos. However, the distinctive, pleasing, and sweet flavor of the pummelo may appeal to the people of Puerto Rico and most other tropical countries that traditionally prefer sweet, low-acid citrus fruits.

## Propagation

When the pummelo is propagated from its own seeds, several results may be obtained. If the variety is highly homozygous, the progeny are likely to be much like the parent. Unfortunately, this degree of uniformity is variable and has been determined only experimentally. If the seeds are obtained as a result of a cross of two highly homozygous parents, uniformity of the progeny can also be expected, but in general they should be intermediate between the parents. When seeds are obtained from heterozygous parents, the progeny can be expected to be highly variable. Few of such progeny will approach the parents in quality. Therefore, in practice pummelos are seldom propagated from seed.

The ancient technique for the propagation of the pummelo was air layering or marcottage. Developed by the Chinese, this technique of inducing root formation on an aerial stem made

possible the propagation of trees exactly like the parental variety. Today this technique is seldom used because budding is considered simpler. On the small scale of the home orchard, marcottage may be a useful technique.

The common practice now is to bud good pummelo varieties on 'African' pummelo seedlings. This method produces better results than grafting to other traditional rootstocks ('Sour' orange, 'Rough' lemon, and others). Terminal cleft grafting also gives satisfactory results.

Seeds should be removed from a mature fruit, washed and dried lightly, and sorted to remove small or damaged seeds. The seed can be stored at cool temperatures for short periods, if immersed 1 minute in a 5% solution of quinoline sulfate, allowed to dry on paper toweling, and sealed in plastic bags for control of fungi. If seeds are planted soon after removal from the fruit, treatment with quinoline sulfate will not be needed. Plant the seeds in seed beds or flats in sterilized soil if possible. On a small scale, sterilization should be practical and will pay off in healthy seedlings. Plant the seeds 2 to 3 cm apart in furrows 8 cm apart about 2 cm deep. It is helpful to cover the seeds with clean sand or pulverized moss. Such seeds, if watered frequently, germinate in about a month. If the soil is reasonably fertile, it should not be necessary to fertilize the seed bed, but if growth is not vigorous, a mineral fertilizer can be applied in small amounts dissolved in water.

When the seedlings are 6 cm in height the weak and off-type seedlings should be eliminated. Then, the healthy seedlings can be transplanted to a well-prepared soil mix in 4-l plastic bags, where they can be grown until ready for budding.

In the Tropics, budding is best accomplished with trees that have not exhausted the nutrients of their container, perhaps at the beginning of the wet season, when new growth is expected. Undesirable shoots are removed several weeks before budding, leaving a clear trunk of 15 cm or more. The budding should be done after trees have been watered well for several days.

When selecting budwood, avoid off-type growth, diseased, or insect-infested branches. Bud sticks circular in cross section, still somewhat green but not produced as the last flush of growth, are usually best. Buds present in the axils of large leaves are desirable for budding. Bud sticks should be kept moist and used within a few days after cutting, if possible.

The T or shield-bud method is the most common. The knife should be sharp. The bud is removed with an oval sliver of wood about 2.5 cm long. Then, the bark of the stock is cut with a vertical cut the length of the bud piece and a horizontal cut at the upper end. The bud piece is then carefully pushed down into the cut beneath the cortex. The buds are wrapped tightly with plastic budding tape. The techniques used for the pummelo do not differ in any way from those used for other citrus species.

The buds can be unwrapped 2 to 3 weeks later if budding is done in warm weather, or later if the weather is cool. Remove the upper part of the stock 6 to 10 cm above the bud when new growth begins, and remove suckers on the stock as they occur. The young grafted plants are often tied to stakes to obtain a straight trunk.

Grafted trees should be ready for planting in the field after 3 to 4 months.

## Transplanting

In many cases, there will be little opportunity to choose the soil for a new pummelo planting, but when such a choice is possible, several factors should be considered. Heavy clay soils should be avoided. Sandy soils are suitable if carefully managed. The upper few feet of soil should be well drained, but a high water table is not necessarily a disadvantage. Bed and ditch systems can be constructed in poorly drained soils. Pummelos prefer moderately acidic soils, but soils that are too acidic should be treated with lime well in advance of planting.

Soil used for planting should be cleared of other trees and weeds long before planting. The soil should be plowed or disked, and leveled as necessary. Brush, roots, and large stones are removed. A planting plan is developed, and the prospective sites for trees are marked. For pummelos, a spacing of 9 by 9 m (124 trees/ha) is recommended. Some system should be adopted to space the trees evenly in order to facilitate grove maintenance and fruit harvest.

Although planting can be done at any time of the year, planting during the rainy season

is recommended. The trees can benefit from the rainy season and will soon begin new growth.

Care should be taken in the selection of the trees for planting. Small, weak, or diseased trees should be rejected, for they will require extra care and be slow in establishment. It is best to carry trees from the nursery to the field the day of transplanting. Exposure of pots to sunlight may overheat tender roots inside. If the trees are bare rooted, they must be wetted frequently and cared for constantly to avoid drying.

The holes are dug by hand or by machine, about three times the diameter of the container and somewhat deeper than the depth of the root system. If the topsoil is underlain by a poor subsoil, the topsoil should be placed to the side to be used in filling the hole. Because tropical soils are often poor, it is well to mix the soil that will go into the hole with well-rotted manure or other organic material before planting. The tree should be placed in the hole at the same depth at which it is planted in the container. Sufficient soil mixture should be placed in the hole to establish the proper level. The tree is pruned of dead or undesirable growth and, if bare rooted, dipped in water. Bare-rooted trees are pruned back. The plastic bag or container is then removed and the tree is placed in the hole. The soil mixture is placed around the tree and tamped to release air bubbles. If the tree is bare rooted, it is well to distribute soil around the roots by hand. After the tree is set, the remaining soil is used to construct a water-retaining ring or basin about 1 m in diameter and up to 10 cm in depth. This basin is then filled with 20 to 40 l of water. The tree should be watered the next day, or two, and thereafter only once or twice a week, according to rainfall. Trees should never be permitted to wilt for lack of water.

## Fertilization

Fertilizer mixed with the soil at the time of planting may damage the roots, especially if they are bare at planting time. During the first few years, trees should be fertilized each 4 months with about 100 g of a mineral fertilizer high in nitrogen and potassium, low in phosphorus, and with magnesium. The amount of fertilizer applied should gradually increase to a stable 3 kg per application.

During the first year, the fertilizer should be spread over the watering basin, but not near the trunk of the tree. The area over which the fertilizer is spread after the first year should be about twice the diameter of the canopy of the tree.

According to the Florida Citrus Spray and Dust schedule for 1976, the application of zinc in nutritional sprays is not economically justified in groves where only widely scattered or mild symptoms of zinc deficiency appear. When extensive deficiency symptoms appear, zinc should be sprayed, preferably in the postbloom period. The amount of zinc (as metal) used in the spray may be varied from 1 kg per 1,200 l for mild to moderate deficiency to 2 kg for somewhat severe deficiency. These rates apply to inorganic zinc sources, such as basic zinc salts or zinc oxide.

Spray application of manganese is recommended for any grove having a persistent manganese deficiency and particularly for groves in alkaline soils. Copper is recommended in nutritional sprays only where a deficiency actually exists and when the element is not used in a disease-control program. Where a boron deficiency is suspected, use 0.3 kg of soluble borate containing 58% or 66% boron equivalent, or 0.35 kg of 46% soluble borate, per 1,000 l.

In the Tropics, it is highly desirable to plant a cover crop or a cash crop that will give a return while the trees are small. Some requisites of the cover crop are that it reduces erosion, avoids competition with the trees, and avoids shading of the trees. Plantains or bananas are useful because they require little care and can easily be removed after 3 to 5 years. Other useful crops include pigeonpeas, hyacinth beans, climbing cowpeas, and tropical kudzu. If vines are used, care must be taken to see that they do not climb the trees.

An area around the trees approximately twice the diameter of the canopy should be kept free of weeds, especially during the early years of growth. Herbicides used for control of weeds in other citrus fruits may be harmful to pummelos. Further study of appropriate herbicides is necessary before recommendations can be made.

### Pruning

The purpose of pruning is to remove dead wood in order to permit the maximum development of an open canopy, to remove branches that might let their fruits touch the ground in order to permit access of farm machinery, and to facilitate harvest. Young trees will need little pruning, except as necessary to form the principal trunks. As trees grow, they may need careful pruning immediately. Drastic cutback of the trees should be avoided.

In the cutting away of a branch, the normal three-cut practice is desirable. The first cut is made from below about 15 cm from the main trunk. The second cut is made from above about 30 cm from the cut. Thus, the first cut protects against splitting as the branch comes away. The third cut to remove the stub should then be made at the main trunk or the fork of the branch. The cut surface should be protected with a commercial pruning paint.

## DISEASES AND INSECTS

With any tree fruit the control of insects and diseases is extremely important. Both cut yield by reducing the vigor of the trees and by damaging the fruit. As controls are sought, it should be remembered that pesticides should be used carefully in accordance with the manufacturer's instructions and limitations of the law. When cultural practices can be used to control a disease, such controls should be given a high priority.

Well-cared-for trees are usually more resistant to pests and diseases than neglected trees. Adequate fertilization, weeding, watering, and pruning away of dead branches and excessively dense foliage are good measures for the protection of the trees.

Each geographical region is troubled by its particular problems. The grower should acquire the best information or recommendations on pests and diseases in his region. The literature of areas of similar climate where citrus is grown may be helpful.

In Puerto Rico, only a few pummelos are found on the entire island. Nevertheless, the pests and diseases are about the same for all citrus species, and the recommendations for citrus in general can be used for the pummelo.

To control scale insects in Florida, the foliage is sprayed with a mixture of petroleum oil and malathion (diethyl mercaptosuccinate *S*-ester with *O,O*-dimethyl phosphorodithioate)[3] (25% wettable powder), 10 l of the former mixed with 6 kg of the latter in 400 l of water. In Puerto Rico, 1 l of petroleum oil plus 0.5 kg malathion per 100 l water is used. It may be necessary to spray several times a year, with good pressure, until the insect attack is reduced to insignificance.

For mites, a miticide such as dicofol [1,1-bis(*p* - chlorophenyl) - 2,2,2, - trichloroethanol] (18.5%) is dusted on the foliage, or carbophenothion [*S*-[[(*p*-chlorophenyl)thio]methyl] *O,O*-diethyl phosphorodithioate] is sprayed on at 0.5 l per 400 l of water.

Scab lesions may occur on the undersides of leaves and on the fruit. Lesions start as small, translucent spots that swell and become colored buff, yellow, orange, or red. If the lesions occur on fruit, it may become permanently scarred or misshapened. Captafol [*cis*-*N*-[(1,1,2,2-tetrachloroethyl)thio]-4-cyclohexene-1,2-dicarboximide] or benomyl [methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate] sprays correctly timed are usually more effective than schedules of copper fungicides at 1.5 to 3 kg of copper (metallic) per 1,000 l of water applied dormant and again at two-thirds petal fall. A single spray of captafol at 8 to 10 l per 1,000 l applied just before growth at the beginning of the rainy season can be sufficient by itself for scab control. Benomyl at 0.4 to 0.6 kg per 1,000 l is most effective when applied shortly before fruit set.

The disease gummosis, or foot rot, occurs as lesions near the soil level, the crown, or the graft union. The tissues of the lesions are discolored or dead, and gums may exude. This is a common disease, especially when 'Rough' lemon is used as a rootstock. A breeding and selection project to develop rootstock tolerant of *Phytophthora* was initiated by the USDA Date and Citrus Station at Indio, Calif. (*10*). Selections of pummelos found tolerant include 'Kao Ruan Tia' and 'Kao Phuang'. Although the 'African' pummelo was not included in these tests, its tolerance has been confirmed since then.

[3] Regarding the use of pesticides on the pummelo, see "Notice to Readers" on page ii.

The incidence of foot rot is reduced by budding trees high above the soil line (15 cm), where infection by splashing is unlikely, by avoiding heavy soils and poor drainage, by pruning to permit free air movement around the trunks of the trees, by controlling weeds under the tree, and by avoiding puddling when irrigating. Injuries to the bark of the tree should be avoided.

An important control measure of foot rot is to remove fruits that fall to the ground. Otherwise they will become infected with *Phytophthora* and liberate large quantities of spores.

If trees do become infected, bordeaux mixture [copper sulfate (monohydrate) + excess of hydrated lime (calcium hydroxide); mixture formed in presence of moisture on plant surface] or one of the other copper compounds is painted on the affected surface. More severe cases are treated by removing part of the soil, cutting away diseased tissue, and painting with one of the above compounds. The labor involved in such treatments and the danger of reinfection make it desirable to avoid gummosis when possible. It is a disease that should be treated as soon as it is found.

Melanose is seen as the development of small, raised, brown spots on leaves, stems, and fruits. It is caused by the fungus *Diaporthe citri* Wolf., especially after any injury to the tree or if part of the wood is killed. Removal of dead wood is one of the best ways to avoid melanose. Young tissues are susceptible to the disease, and so precautions should be taken especially at the time of new growth and flowering. Captafol and copper-based fungicides are used to control the disease. In Puerto Rico, fixed copper, 2 kg per 1,000 l of water, is recommended as a spray applied when flowers open, after fruit set begins, and when fruits are 1.5 cm in diameter. Captafol at 8 to 10 l per 1,000 l of water should be applied just before new-shoot growth at the beginning of the rainy season. Do not apply it when fruits are mature, because it can damage young leaves and blemish fruit.

Damping-off in the seed bed resulting from *Pythium*, *Phytophthora*, or *Rhizoctonia* can be controlled by preplanting fumigation of the soil.

It is highly recommended that pummelo growers become acquainted with disease and insect-control practices near their prospective plantings, so that control measures can be learned, and equipment and chemicals can be acquired in advance.

## HARVEST

In a typical, hot tropical climate in Southeast Asia, there is no cold-induced dormancy period, and hence bloom "flushes" normally follow periods of drought-induced dormancy (*4*). In Thailand, pummelos, like most other citrus species, bloom about four times each year, depending on the seasonal rainfall. The heaviest bloom appears in June at the beginning of the rainy season, and fruit produced from the June bloom usually matures in November. But because of three other blooming periods, there are usually four fruit-harvesting seasons (*16*).

In Puerto Rico and the Caribbean, bloom flushes normally follow a period of drought, resulting in off-bloom crops of fruit being set, depending on the rainfall. Consequently, there may be mature fruit on the trees most of the year. While there may be one main harvesting season (December to March), the harvesting of off-bloom fruit may be done according to the demand.

In Thailand, the main crop is picked just before the fruit is mature. At this stage it has attained its natural size, but the rind is still green and just starting to turn yellow. If the fruit is allowed to mature on the tree, the juice sacs are apt to develop a "kao sarn" raw rice condition (*16*).

The best quality fruits are those that have been cured during storage (*16*). After storage of 1 to 2 months, the rind is soft, fragrant, distinctly yellow, and wrinkled. At this stage the fruit becomes juicy and has a better flavor than if allowed to ripen on the tree. If fruits are carefully handled at harvesting, little to no spoilage occurs during storage. The fruit is stored in baskets in a well-ventilated room, usually on rafters under a palm-roof house.

It is quite likely that pummelo fruits, like lemons, require curing for attainment of highest fresh fruit quality. The process of curing lemons before shipping was introduced in California about 1880 (*24*). At that time it was a practice to spread the fruit in a dry place in the shade for 3 to 4 weeks before shipping. Out of this developed the practice of picking

the fruit while still green and holding them for an extended period in controlled-temperature curing rooms. Such lemons degreen naturally in storage, giving good quality fruit that is preferred to tree-ripened fruit. When rapid degreening of green-harvested fruit is desired, it is easily attained by appropriate use of ethylene (*7*).

There is a need for research in the curing of pummelos, especially with the main-harvest crop. This could possibly lead to a more orderly marketing of the fresh fruit, as well as improved fruit quality. The volume of fruit produced in the off-bloom crops may not justify storage in these instances.

Because of the thick rind, the pummelo is one of the best citrus fruits to pack and ship. The large but soft fruit can be packed tightly with little danger of bruising. The use of small-fruiting varieties, such as the 'Nakon', will increase the number of fruit per container and lower the sale price per fruit.

## USES

Pummelos are commonly grown in southern Mexico, and a large number of them are sold directly on the farmers' market. They are displayed in large piles, and the purchaser picks out the fruit he wants. The production of fruit for sale in the local markets would probably be the best opportunity for introducing the pummelo to the people of the American Tropics, so that the great expense of packing and shipping can be avoided.

The pummelo is an excellent keeper, and can be purchased in large quantities for household use. Pummelos are almost always used as a dessert or salad fruit and are welcome at any meal. They should never be served like grapefruit, for it is difficult to remove the pulp from the skin.

The rind clings tightly to the sections, and considerable art is required to open the fruit in an attractive manner for serving. The Siamese frequently cut the fruit longitudinally into irregular pieces and then tear apart the fleshy sections, finally stripping off the rind and removing the seed. The partition walls are thick and tough and therefore should be stripped from the pulp sections before the latter are eaten. Each section of the fruit, when stripped of its partition membrane, reveals a large mass of attractive pulp vesicles that readily fall apart and that can be separated by the fingers and carried to the mouth without causing any juice to escape (fig. 4). These vesicles are burst in the mouth by pressure from the tongue, releasing juice with no trace of rag. These fruits are exceedingly juicy and possess a delightfully sweet, mildly acidic flavor.

If some mechanical means could be developed to remove the pummelo sections, such sections would probably make an excellent canned or frozen-food product. The consumer would be relieved of the art of preparing the sections. This relief would enhance the value of the fruit for the housewife.

Some minor uses of the pummelo merit mention. The whole fruit makes excellent jam or marmalade, although slices must be sectioned because of their large size. The peel can be candied and is similar to the citron. The large, fragrant flowers are extracted as a source of perfume. The leaves are cooked as a tea and used for ulcers in Malaysia. The wood is tough and good for tool handles.

The future of the pummelo in the Western Hemisphere depends upon the efforts made to use it. Since good varieties are already available, it should not be necessary to introduce new ones. Distribution of the current varieties and trials in many soils and climatic situations would help to identify locally adaptable varieties.

But this may not be enough. Positive efforts need to be made to introduce the pummelo to those who might use it. Suitable scientific, farming, and popular publications are needed. as well as frequent press and television coverage. Demonstrations of the fruit to potential

FIGURE 4.—Sections of pummelo fruit and fruit vesicles removed for eating.

growers and consumers would aid this process. During the early stages, it would be useful to establish pummelo trees in many public and private places. When pummelos are well known, it should be easy to induce growers to produce them.

Then a further step will be necessary: the detailed development of pummelos for specific areas. This research will sometimes include breeding, but it will mainly consist of the development of appropriate techniques for dealing with the problems of the region.

A collection of varieties under development at the Mayagüez Institute of Tropical Agriculture, Mayagüez, P.R., will make propagating materials available on a wider basis. With a determined interest, it should be possible to popularize pummelo, at least in Puerto Rico, for example, within 20 years.

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